This exam will focus on electromagnetic transitions. Show all work where appropriate. Tables of possibly useful physical quantities are provided at the end of this exam. The exam is graded out of 100 points with the point breakdown indicated next to each question.

1. (5 points) Consider the transition of a single proton from an initial excited state to the final ground state of a particular nucleus involving a change in the distribution of neutrons and protons. Schematically describe the difference between electric and magnetic transitions.

2. (10 points) Estimate the nuclear recoil resulting from the emission of a 233-keV gamma ray from ^{133m}Xe.

3. (10 points) The ground state of ^{72}Ge is 0^+. The first two excited states are 0^+ and 2^+ at energies of 691 and 834 keV, respectively. The transition between the first excited 0^+ state and the ground state is forbidden to occur through gamma-ray emission.
   a. What are the likely gamma-ray transitions (provide energy and multipolarity) from 2^+ state at 834 keV?
   b. Why is the transition from the excited 0^+ state to the ground state forbidden?
   c. What is the de-excitation mechanism of the 691 keV state?

4. (10 points) Reproduce the table below in your blue book and complete the third and fourth columns. The third column represents the change in orbital angular momentum (l) for each transition and the fourth column indicates whether parity change occurs or not.

Name	Δl	Δparity
Electric dipole		
Magnetic dipole		
Electric quadrupole		
Magnetic quadrupole		
Electric octopole		

5. (15 points) ^{135}Xe has an J^{π} = 11/2$^-$ isomeric state at 526.6 keV which decays directly to the ground state with a half-life of $t_{1/2}$ = 15.3 minutes. A pure isomeric sample was obtained and the decay of the 11/2$^-$ state was monitored. A total of 10,000 526-keV gamma rays, 1950 492-keV conversion electrons, and 336 conversion electrons in a group of unresolved transitions at 521 keV, all corrected for detection efficiency, were observed and attributed to the decay of the isomeric state.
   a. What is the internal K-conversion coefficient?
   b. What is the multipolarity of the isomeric transition based on predicted conversion coefficients presented in Fig. 1 at the end of this exam?
   c. What is the spin and parity of the ^{135}Xe ground state?
   d. What is the binding energy of the K-shell electron?
   e. Suggest the origin of the unresolved transitions at 521 keV.

6. (10 points) Electromagnetic transition rates are directly proportional to the reduced transition probability, B($J^{\pi}_i \rightarrow J^{\pi}_f$) according to the following equation:

$$\lambda\left(\ell, J_i^{\pi} \rightarrow J_f^{\pi}\right) = \frac{8\pi(\ell+1)}{\ell[(2\ell+1)!!]^2}\frac{k^{2\ell+1}}{\hbar} B\left(\ell, J_i^{\pi} \rightarrow J_f^{\pi}\right)$$

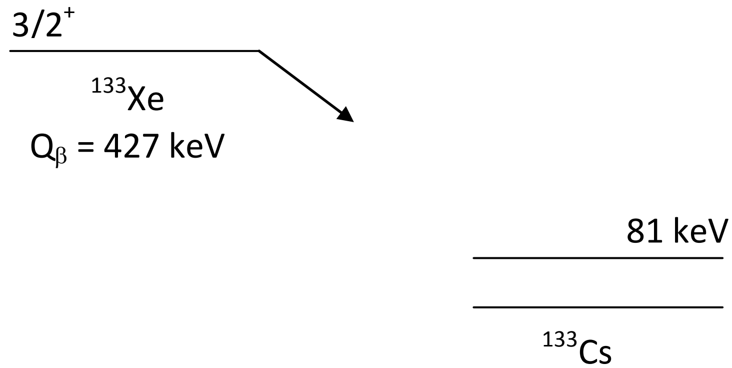
The reduced transition probability B($J^{\pi}_i \rightarrow J^{\pi}_f$) is the matrix element for the multipole operator, O(L), (either electromagnetic or magnetic):

$$B\left(\ell, J_i^{\pi} \rightarrow J_f^{\pi}\right) = \sum_{\mu M_f} |< J_f M_f|\, O(\ell\mu)\, |J_i M_i| >^2$$

A simple estimate for transition rates was derived by Weisskopf and provides a guide for evaluating the nature of electromagnetic transitions. Describe in words, with equations if necessary, the assumptions made to derive the Weisskopf estimates.

7. (10 points) The beta decay of ^{135}Xe predominately proceeds through a transition to the first excited state in ^{135}Cs at 249.8 keV. The spin and parity of the ^{135}Cs first excited state and ground state are 5/2$^+$ and 7/2$^+$ respectively.
   a. List all possible multipolarities that could contribute to the gamma-ray transition between the first excited state and the ground state in ^{135}Cs.
   b. List the likely mulitpolarities that will contribute to the gamma-ray transition between the first excited state and the ground state.

8. (20 points) The nucleus ^{133}Xe can be used as a monitor of clandestine nuclear weapons tests. Detecting the presence of ^{133}Xe in an atmospheric air sample is accomplished by monitoring either the IT decay of an isomeric state in ^{133}Xe or through the gamma rays emitted following the beta decay of ^{133}Xe to ^{133}Cs. Reproduce the following figure in your blue book.



Based on the data provided in the table below construct the level scheme of ^{133}Cs populated in the beta-decay of ^{133}Xe. Indicate the energy and spin and parity of each level and multipolarity of all gamma-ray transitions.

Transition energy (keV)	Comments
79.6	In coincidence with 81.0 and 223.2 keV transitions
81.0	$t_{1/2}$ = 6.283 ns, populates a 3/2+ transition
160.6	M1+E2
223.2	M1 + E2, in coincidence with 79.6, 81.0, and 160.6, keV transitions
302.8	in coincidence with 81.0-keV transition
383.8	α_K = 0.017

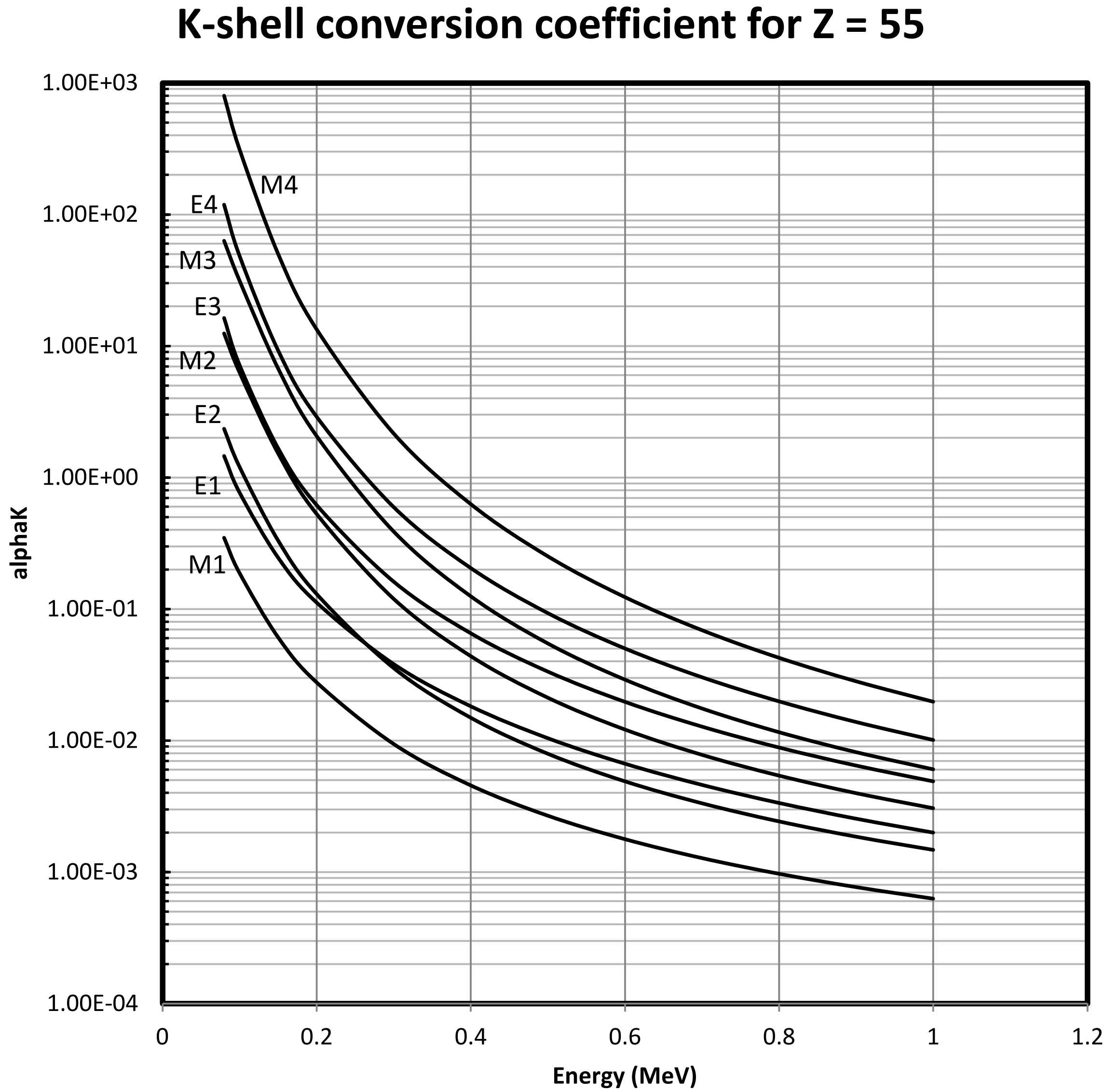
9. (10 points) Assignment of spins and parities to individual levels in a nucleus is greatly aided by a measurement of a gamma-ray angular distribution. In typically laboratory settings, the various m_i substates of a nuclear level with total spin and parity J^π are equally populated resulting in an isotropic emission of gamma-rays from the level. Suggest two mechanisms for creating an unequal population of the m_i substates.

Table 1: Weisskopf estimates for selected electric and magnetic transitions

Multipolarity	Transition rate (s^{-1})	Multipolarity	Transition rate (s^{-1})
E1	$1.0\ x\ 10^{14} A^{2/3} E_\gamma^3$	M1	$3.2\ x\ 10^{13} E_\gamma^3$
E2	$7.3\ x\ 10^{7} A^{\frac{4}{3}} E_\gamma^5$	M2	$2.2\ x\ 10^{7} A^{\frac{2}{3}} E_\gamma^5$
E3	$3.4\ x\ 10^{1} A^{2} E_\gamma^7$	M3	$1.0\ x\ 10^{1} A^{4/3} E_\gamma^7$
E4	$1.1\ x\ 10^{-5} A^{\frac{8}{3}} E_\gamma^9$	M4	$3.8\ x\ 10^{-6} A^{2} E_\gamma^9$

Table 2: Masses for selected neutron-rich Xe isotopes

Isotope	Mass (amu)
130Xe	129.903
131Xe	130.905
132Xe	131.904
133Xe	132.906
134Xe	133.905
135Xe	134.907


K-shell conversion coefficient for Z = 55
1.00E+03
1.00E+02
1.00E+01
1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
alphaK
0
0.2
0.4
0.6
0.8
1
1.2
Energy (MeV)
M4
E4
M3
E3
M2
E2
E1
M1